

**Multi-Element GPS Antenna Array on an  
RF Bandgap Ground Plane**

**Final Technical Report**

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13. ABSTRACT (Maximum 200 words)  Antenna arrays on conventional ground planes present different deficiencies. For compact platforms, the propagation of RF surface currents results in lost power, radiation from the edges and other discontinuities. It also contributes to the strong coupling and causes blind angles and multipath interference. By building radio isolation into the ground plane of phased array antenna structures, it is possible to reduce these different disturbances. This isolation may be achieved by using corrugated surfaces. In this case, DC currents are conducted but not AC currents. Based on the previous work done on PBG structure, a new kind of surface called High Impedance Ground Plane can be used. This kind of ground plane presents the same characteristics are corrugated surfaces in all the directions. Moreover the thickness must no longer be one fourth of the wavelength and can be even much smaller. These ground planes have been applied antenna array in order to reduce the disturbances created on compact platforms. Phase measurements of two-dipole array clearly shows this reduction.				
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**Eli Yablonovitch** – Principal Investigator

**Subject:** Multi-Element GPS Antenna Array on an RF Bandgap Ground Plane

**Purpose of the work:**

Antenna arrays on conventional ground planes present different deficiencies. For compact platforms, the propagation of RF surface currents results in lost power, radiation from the edges and other discontinuities. It also contributes to the strong coupling and causes blind angles and multipath interference.

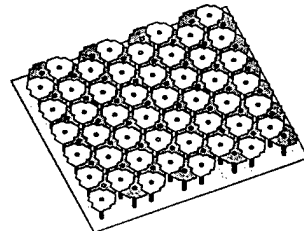
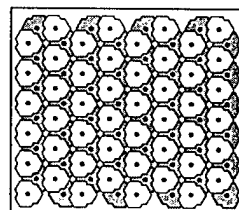
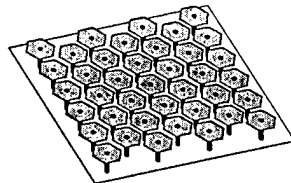
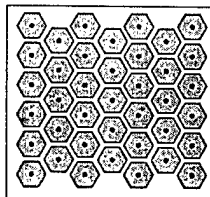
By building radio isolation into the ground plane of phased array antenna structures, it is possible to reduce these different disturbances. High Impedance Ground Planes are the solution proposed to solve these issues.

**Statement of the work:**

- *Design of high impedance ground plane.*
- *Reduction of the dimensions to work within the GPS band.*
- *Design of the elementary source placed above the ground plane.*
- *Realization of a two element array and demonstration of the reduction of phase distortion.*
- *Realization of the 30 element array antenna.*

**Progress:**

The first step of this work has been the reduction of the dimensions. This reduction has been possible by no longer using fringing capacitance -Fig.1- but by using facing capacitance. In this case, a third layer must be added to the structure -Fig.2-.



*Fig.1: 2-layer structure*

*Fig.2: 3-layer structure*

Then, a structure has been design and characterized. The phase of the reflection coefficient measurement has showed a zero-phase crossing frequency of 2.35GHz and the surface wave band-gap, obtained by surface wave measurements, has been observed between 2.25 and 2.60GHz.

As the phase of the reflection coefficient is equal to 0deg inside the band-gap, it is possible to lie an antenna right above the substrate. A monopole antenna has been used as the source. A kink has been added in the shape of the monopole in order to improve the input impedance matching to 50Ω -Fig3-.

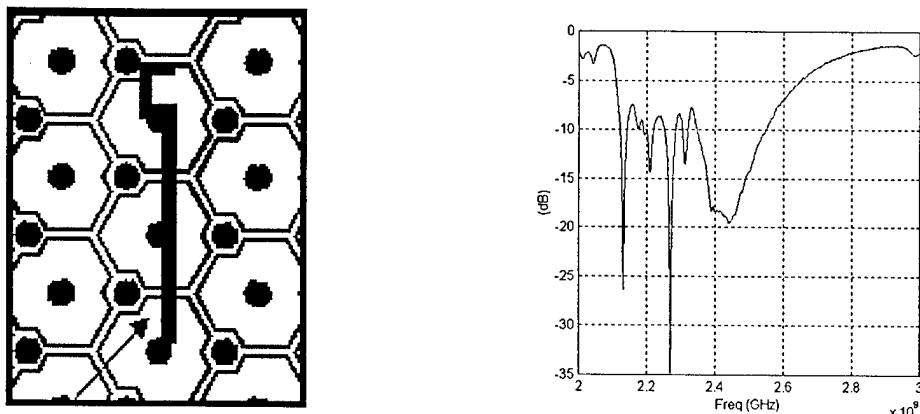


Fig.3: Monopole on 3-layer high impedance ground plane and input return loss.

The radiation pattern obtained for such a structure exhibits a front to back radiated field ratio greater than 12dB, even when the dimensions of the board are  $0.4\lambda$  by  $0.2\lambda$ . It demonstrates that surface currents have been dramatically reduced. Therefore, the field is rather radiated frontward. The high impedance ground plane also gives to the input impedance of the antenna a great immunity against disturbances, when the antenna is placed in a really configuration.

In order to validate the reduction of the phase distortion when multiple antennas are placed very near on the same ground plane, received signal phase measurements have been performed when one and two antennas are above the ground plane. The measurements have been done for two antennas either parallel or straight as presented in Fig.4, in a configuration GPS application: with an angle of incidence of approximately 60deg -Fig.5-.

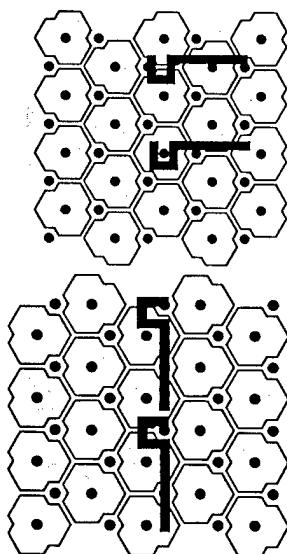


Fig.4: Monopole configurations.

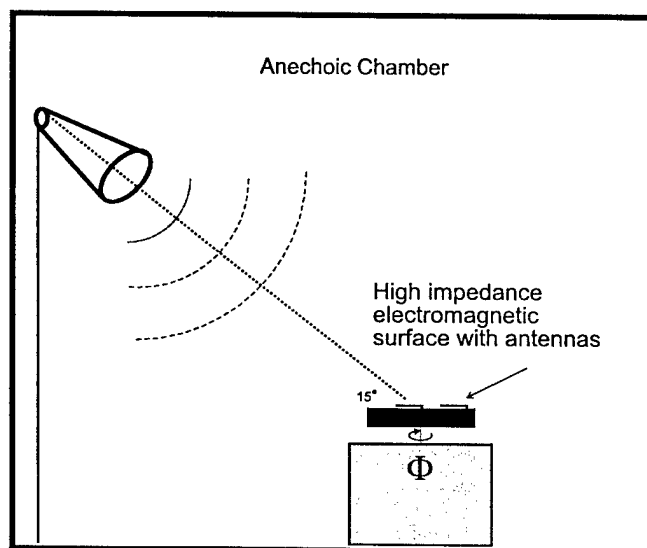
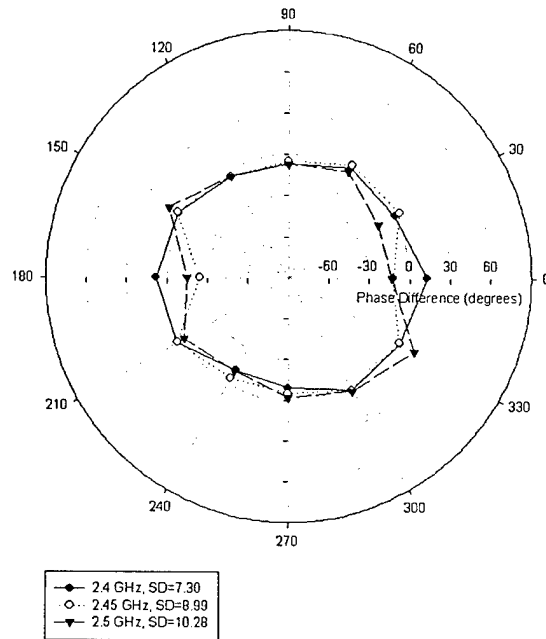
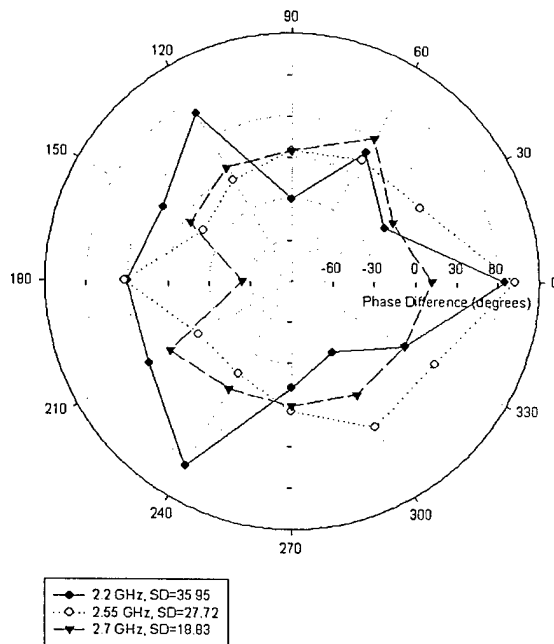


Fig.5: Measurement configuration.

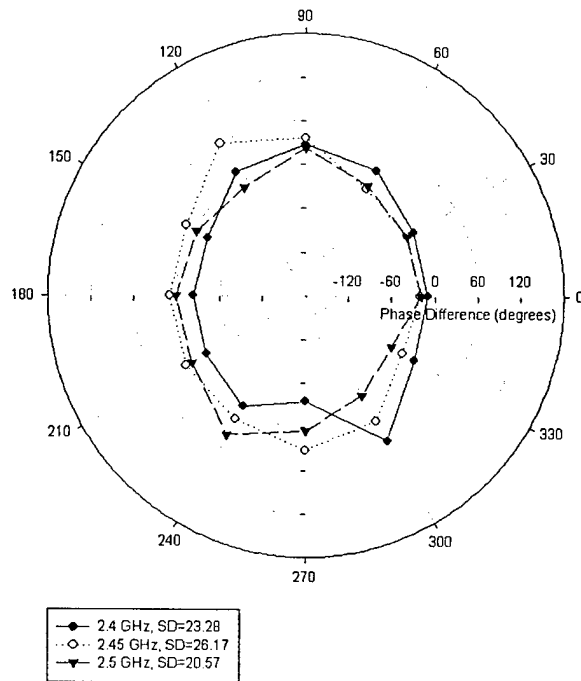
Then, the phases of the field measured in the presence one and two antennas have been subtracted, either inside or outside the band-gap. Results for both physical configurations (monopole parallel or straight) and for both frequency configurations (inside or outside the band-gap) are presented in Fig.6.



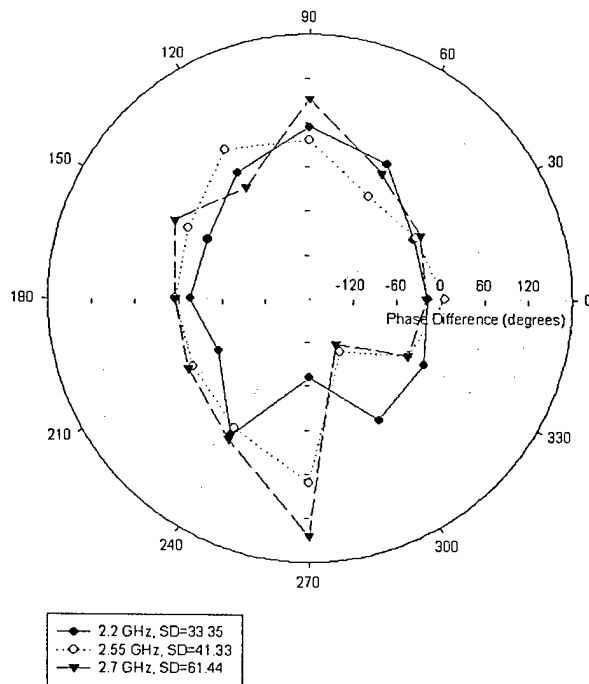
*Fig.6-a: Straight monopoles excited at a frequency inside the band-gap*



*Fig.6-b: Straight monopoles excited at a frequency outside the band-gap*



*Fig.6-c: Parallel monopoles excited at a frequency inside the band-gap.*



*Fig.6-d: Straight monopoles excited at a frequency outside the band-gap.*

These results shows that inside the band-gap, the phase difference is nearly constant and equal to 0deg all around the 360deg whereas outside the band-gap, the

coupling between the two antennas disturbs the phase of the received signal. The distortion on the phase also depends on the direction of incidence. The biggest distortion is observed when the direction is perpendicular to the monopole axis. Therefore, high impedance ground planes used inside the band-gap allow a reduction of distortion of the received signal phase in the case of a compact antenna array.

The following step of this work are the design of the high impedance ground for the GPS frequency band, around 1.55GHz and the construction and assembly of the full GPS array at 1.5GHz. The frequency shifting from 2.45 to 1.55GHz can be obtained by a scaling factor.

#### **Publications:**

1. R. Broas, "Experimental Characterization of High Impedance Electromagnetic Surfaces in the Microwave Frequency Regime", Master of Science Thesis Dissertation, UCLA, 1999.
2. Sievenpiper, D.; Lijun Zhang; Broas, R.F.J.; Alexopolous, N.G.; Yablonovitch, E. , "High-impedance electromagnetic surfaces with a forbidden frequency band.," IEEE Transactions on Microwave Theory and Techniques, vol.47, (no.11), IEEE, Nov. 1999. p.2059-74